A NEW SPECIES OF *TOXALA* MOULDS (CICADIDAE: CICADETTINAE: CICADETTINI) FROM NORTH QUEENSLAND, WITH NOTES ON ITS CALLING SONG AND COMPARISONS WITH A CONGENERIC SPECIES

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Abstract

Toxala Moulds was previously a monotypic genus of small grass cicadas known from central eastern Australia. A new species is described from the Herberton district in north Queensland, Australia, extending the distribution of this genus. The new species has been found in open grassy woodland with sparse heath elements, the adults of which are associated with grass and have been collected during late December to early January. The single known population appears to be highly localised and is potentially prone to habitat disturbance. Additional distribution records are provided for *Toxala verna* (Distant) from southeastern Queensland. First documentation of the calling songs of the two *Toxala* species is also provided, along with comparative notes.

Introduction

The grasslands of Australia are occupied by a diverse array of small cicadas from approximately 17 different genera. These have been the subject of several recent taxonomic studies (*e.g.* Ewart 2005, Ewart and Marques 2008, Ewart 2013). Many of the species appear to be grassland specialists, with adults emerging in large numbers after rainfall and, in most cases, normally persisting for only two weeks. The ephemeral nature of their appearance has generally resulted in infrequent opportunities for collection and observation. As a result, much of their natural history and species diversity remains poorly understood.

The genus *Toxala* was introduced by Moulds (2012) as part of a substantial review of Australian cicada genera. *Urabunana verna* Distant was included as the type species of this new genus. Here, I describe a second (new) species of *Toxala* from north Queensland and provide additional distribution records for *T. verna*. A first description of the calling songs of both species is also given, along with some discussion on similarities and differences between the two species.

Methods

Anatomical terminology follows Moulds (2005, 2012) for body structures and wing characters, Dugdale (1972) and Moulds (2005) for genitalia, de Boer (1999) for opercula, and Simmons and Young (1978), Dugdale (1972) and Bennet-Clark (1977) for timbals. The long timbal ribs are referred to sequentially as long ribs numbered 1 to 5, with long rib 1 being the most posterior (adjacent to timbal plate). The higher classification adopted in this paper follows Moulds (2012). Measurements (in mm) are given as ranges and means (in parentheses) and include all specimens available. Head width spans

across the outer margins of the compound eyes; pronotum width across the extremities of the lateral margins (excluding ampliated lateral angles); abdomen width is measured across the outer edges of the auditory capsules.

Collection Institution abbreviations

AE – private collection of A. Ewart, Caloundra; AM – Australian Museum, Sydney; ANIC – Australian National Insect Collection, Canberra; DE – private collection of David Emery, Sydney; LWP – private collection of L.W. Popple, Brisbane; MSM – private collection of M.S. Moulds, Kuranda; QM – Queensland Museum, Brisbane.

Calling song analysis techniques

The description of calling songs broadly follows Ewart and Marques (2008). The term phrase describes the highest level repeated sequence in a calling song. Within each phrase, a number of finer structures are present. These are described in the following text, in order of increasing duration. A 'pulse' is defined as a single complete movement of the timbals. The term 'syllable' applies to the smallest grouping of pulses (typically 5-10 ms duration). Where multiple syllables occur in succession, without coalescence (*i.e.* where the syllables are spaced by short periods of silence), this is termed a 'syllable train'. Where 2-9 syllables coalesce, these become a 'macrosyllable'. Longer durations of continuous sound (≥10 syllables) are known as an 'echeme'. All of these features have been identified in the calling songs of *Toxala* cicadas.

Field recordings have been used preferentially for song analysis. All recordings were obtained from a distance of at least 20 cm from the calling cicada to reduce the chances of near-field effects. None of the recordings displayed signs of amplitude clipping due to microphone overload.

I obtained audio recordings using a Sony MZR700 minidisc recorder with Sony ECM-MS957 Electret Condenser microphone (frequency response up to 18 kHz). Container recordings of *T. verna* by A. Ewart were also examined for the purposes of this study. These were made using a Sony WM-D6C Walkman with Sennheiser K6/ME66 microphone (frequency response up to 18 kHz).

Processing and analysis of recordings was undertaken with Cool Edit Pro (Version 2.1) software. Amplitude spectra were analysed using a linear frequency axis on a 1024-point Fast Fourier Transform with a Hamming window function.

Systematics

Genus *Toxala* Moulds

Diagnosis follows Moulds (2012), except for the following amendment to accommodate the new species: *Hind wing* with 3-5 apical cells.

***Toxala mckinnonae* sp. n.**

(Figures 1A-B, 2-3)

Type material. Holotype ♂, QM reg. no. T228767, AUSTRALIA (QUEENSLAND): 'Hornet Hill', Herberton district, 3.i.2007, L. Popple, M. & A McKinnon, 17°23'22"S 145°21'02"E, 328-0001 (QM). *Paratypes*: 1 ♂, same location as holotype, 29.xii.2007, L. Popple, A. McKinnon, 328-0015 (AE); 1 ♂, same location as holotype, 29.xii.2007, L. Popple, A. McKinnon, 328-0014; 1 ♀, same data as holotype, 328-0008 (both AM); 1 ♂, same location as holotype, 29.xii.2007, L. Popple, A. McKinnon, 328-0016 (DE); 5 ♂♂, 1 ♀, same data as holotype, 428-0002 to 428-0006, 428-0009; 4 ♂♂, same location as holotype, 29.xii.2007, L. Popple, A. McKinnon, 328-0010 to 328-0013 (all LWP); 1 ♂, same location as holotype, 29.xii.2007, L. Popple, A. McKinnon, 328-0017 (MSM); 1 ♀, same data as holotype, 328-0007, QM reg. no. T228768 (QM).

Description

Male (Figs 1A, 2)

Head. Supra-antennal plate variable, often pale brown anteriorly and dark brown posteriorly, or predominantly dark ochraceous; vertex and frons black; mandibular plates black with conspicuous silver pubescence; genae black, sometimes with light brown colouration adjacent to edges of postclypeus, covered by silver pubescence; small, dull pale brown median orange-brown triangular fascia, extending and widening posteriorly from near median ocellus to pronotal margin along the epicranial suture; ocelli red; compound eyes brown to dark brown. Postclypeus predominantly black, pale brown in anterior median area and along margins and between the transverse ridges, sometimes grading from black through ochraceous to pale brown; anteclypeus mainly black, with silver pubescence; rostrum brown, dark brown at apex; antennae dark brown to black.

Thorax. Pronotum mainly brown to dark brown, with a brown to dull pale brown medial fascia, bordered with dark brown to black colouration that widens anteriorly of pronotal collar and also towards proximal margin; dorsal and lateral fissures inconspicuous, brown to dark brown; pronotal collar brown to dull pale brown, with lateral margins ampliate and tending dark brown. Mesonotum with submedial sigilla dark brown to black, fused anteriorly, with rounded posterior terminations; lateral sigilla black, prominent, elongated and narrowing posteriorly; dorsolateral fasciae brown to dark brown and narrow along parapsidal suture, broadening conspicuously to anterior of scutal depressions, fused or black in intervening medial area; remainder of mesonotum, including lateral edges adjacent to lateral sigilla and area surrounding scutal depressions, brown, becoming pale brown at margins; scutal depressions black; cruciform elevation brown to pale brown, bordered with areas of silver pubescence. Metanotum brown anteriorly, pale brown along posterior margin.

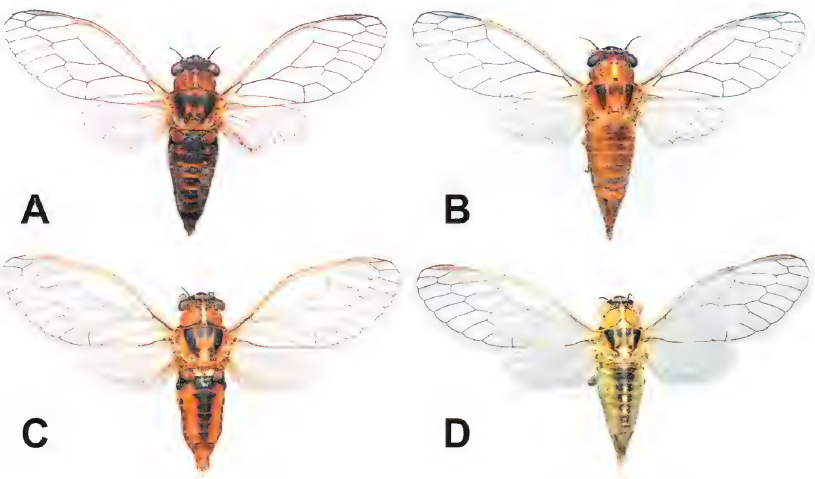

Fig. 1. (A-B) *Toxala mckinnonae* sp. n., 'Hornet Hill' west of Herberton, northern Queensland (17°23'S 145°21'E), (A) male (body length 10.5 mm), (B) female (body length 12.0 mm); (C-D) *T. verna* (Distant), base of Blackbutt Range, southeastern Queensland (26°53'S 152°13'E), (C) male (body length 11.8 mm), (B) female (body length 12.1 mm).

Wings. (Fig. 2A). Forewing costal vein translucent, swollen, pale brown throughout; other venation brown, darker proximally; pterostigma medium to dark brown, semi-opaque; basal membrane grey. Hind wing venation brown, with grey, partly opaque plaga around margins of anal cell 3, adjacent to vein 3A and vein 2A; five apical cells.

Legs. Coxae and trochanters predominantly pale brown with irregular dark brown fasciae on anterior, lateral and posterior faces of fore and mid coxae; fore, mid and hind femora pale brown with brown longitudinal fascia developed on posterior, dorsal and anterior faces; fore tibiae pale brown to brown; mid tibiae and hind tibiae pale brown; tarsi a mixture of pale brown and brown; claws brown, darker apically; spines of fore femora dark brown.

Opercula. (Fig. 2B). Predominantly pale brown to grey; dark brown to black anteriorly; with silver pubescence; meracanthus spike dark brown with paler lateral margins, barely overlapping opercula.

Timbals. (Fig. 2C). Four long ribs; long ribs 1-4 fused dorsally to basal spur; ribs 1-2 spanning across timbal membrane, fused ventrally; long ribs 3-4 both shorter than posterior long ribs 1-2; long rib 3 apparently discontinuous, with separate ventral section.

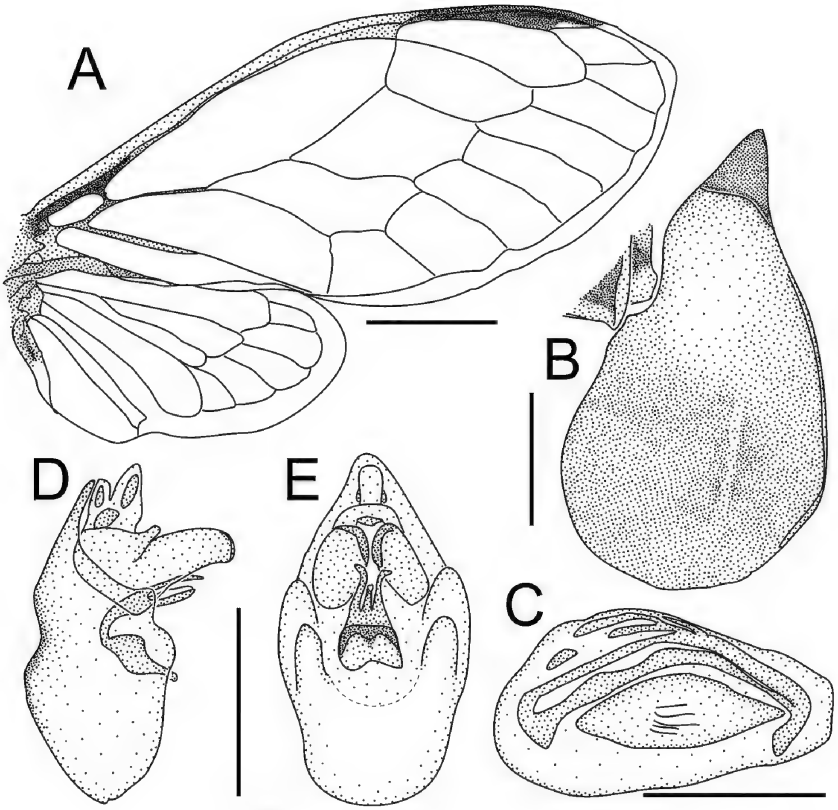

Fig. 2. *Toxala mckinnonae* sp. n. male from 'Hornet Hill' west of Herberton, northern Queensland: (A) fore and hind wings; (B) left operculum; (C) left timbal (anterior margin at top, dorsal margin at right); (D) pygofer lateral view; (E) pygofer ventral view. Scale bars are 1 mm, except wings (2 mm).

Abdomen. Tergite 1 mainly black, brown to dark brown laterally; tergite 2 mainly black, grading through brown to pale brown on posterior dorsolateral half; remaining tergites mainly black, with areas of brown colouration on posterior dorsolateral surfaces and along lateral margins; silvery pubescence most prominent along lateral edges of tergites. Sternite I dark brown to black; sternite II dark brown medially, pale brown over remainder; sternites III to VII brown to pale brown, paler posteriorly, with subtle, brown medial areas; sternite VIII dark brown; intersegmental membranes yellow-brown.

Genitalia. (Fig. 2D-E). Pygofer with black colouration dorsally, becoming dark brown along beak and dark brown to brown along anterior lateral edges; pale brown over the remainder; claspers conspicuously elongated, extending

posteriorly beyond termination of pygofer, bluntly rounded apically; uncus vertically narrow, relatively short, with rounded, beak-like termination; pseudoparameres slightly longer than endotheca and ventral support; endotheca long and fleshy, extending almost as far as ventral support.

Female (Fig. 1B)

Similar to male in general colouring and patterning, although conspicuously paler overall.

Head. Supra-antennal plate and vertex mottled brown to pale brown; frons ochraceous with pale brown area extending medially from anterior of median ocellus; mandibular plates and genae dark brown; small median pale brown triangular fascia, extending and widening posteriorly from near median ocellus to pronotal margin along the epicranial suture; ocelli pink to red; compound eyes brown to dark brown. Postclypeus dark brown with median area, margins and area between the transverse ridges pale brown; anteclypeus dark brown to ochraceous; rostrum brown, darker posteriorly; antennae dark brown.

Thorax. Pronotum mainly pale brown, with a brown to dull yellow-brown medial fascia, bordered with brown colouration that widens and darkens anteriorly of pronotal collar; dorsal and lateral fissures relatively inconspicuous, brown; pronotal collar pale brown to yellow-brown, with lateral margins ampliate and tending dark brown. Mesonotum with submedial sigilla dark brown, unfused, with rounded posterior terminations; lateral sigilla dark brown, prominent, elongated and narrowing posteriorly; dorsolateral fasciae brown to pale brown and narrow along parapsidal suture, broadening conspicuously to anterior of scutal depressions, fused in intervening medial area; remainder of mesonotum, including lateral edges adjacent to lateral sigilla and area surrounding scutal depressions, brown to pale brown; scutal depressions dark brown; cruciform elevation pale brown, bordered with areas of silver pubescence. Metanotum pale brown.

Legs. Coxae and trochanters predominantly pale brown to brown; fore, mid and hind femora pale brown with brown longitudinal fascia developed on anterior faces; fore tibiae mainly brown; mid and hind tibiae pale brown; tarsi a mixture of pale brown and brown; claws brown, darker apically; spines of fore femora dark brown.

Abdomen. Tergite 1 mottled pale brown; tergites 2–8 pale brown with lines of dark brown to brown colouration extending from anterior median dorsal and lateral surfaces; abdominal segment 9 pale brown, with a pair of brown dorsolateral fasciae, extending from the anterior margin and not reaching the posterior margin; stigma brown, inconspicuous. Sternites pale brown, with subtle brown medial areas extending from anterior margin and fading towards posterior; gonocoxite IX brown; intersegmental membranes yellow-

brown. Ovipositor sheath extends <1 mm beyond the posterior termination of abdominal segment 9.

Measurements. N = 14 ♂♂, 3 ♀♀. Ranges and means (in parentheses), mm; body length: ♂♂ 9.7-10.7 (10.3); ♀♀ 12.0-12.4 (12.2); forewing length: ♂♂ 10.6-11.8 (11.2); ♀♀ 11.9-12.4 (12.2); forewing width: ♂♂ 4.0-4.4 (4.2); ♀♀ 4.0-4.3 (4.2); ratio of forewing length to width: ♂♂ 2.6-2.9 (2.7); ♀♀ 2.8-3.1 (2.9); head width: ♂♂ 2.4-2.8 (2.6); ♀♀ 2.7-2.9 (2.8); pronotum width: ♂♂ 2.1-2.3 (2.2); ♀♀ 2.3-2.5 (2.4); abdomen width: ♂♂ 2.5-2.7 (2.6); ♀♀ 2.6-2.8 (2.7).

Etymology. Named after my wife, Ms Anne-Marie McKinnon, an observant entomologist and photographer who was the first person to detect the presence of this small, unique cicada.

Distinguishing characters. Toxala mckinnonae can be distinguished from the related *T. verna* by having five apical cells in both hind wings (the latter species has only three to four cells in each wing, or five in one wing if aberrant). In addition, *T. verna* exhibits much more contrasting colouration (black and orange-brown in males and black and greenish or straw brown in females), whereas *T. mckinnonae* males are a subtler combination of brown and dark brown to black and females are mainly pale brown with dark brown markings.

Distribution, habitat and seasonality. This species is currently known only from a single locality, known colloquially as 'Hornet Hill', west of the township of Herberton in northeastern Queensland (Fig. 3). Adults occur in grass on the edges of grassy woodland and areas of open grassland on sandy loam soils with heath habitat elements (*e.g. Melaleuca nodosa*). The single known population appears to be highly localised and as such may be vulnerable to fire and other habitat altering practices. Specimens have been collected at the height of summer between late December and early January following storms just prior to the onset of the wet season. The appearance of the species and/or its seasonality may be irregular, as adults were not found during subsequent visits to the site by the author on 7 January 2008 and 26 December 2010.

Additional specimen records of *Toxala verna* Distant

The former distribution of *T. verna* and new distribution records are depicted in Fig. 3. Additional specimen records are as follows: 1 ♀, Foothills of Bluff Range, 13-14.xii.1971, H. Frauca (ANIC); 4 ♂♂, SEQ: 27°32'S 153°10'E, J.C. Trotter Park, Burbank, 7.ii.1998, L.W. Popple; 1 ♂, same data as previous, 19.ii.1998; 2 ♂♂, 1 ♀, same data as previous, 24.i.1999; 1 ♂, same data as previous, ii.2008, L. Popple and A. McKinnon; 3 ♂♂, 1 ♀, SEQ: 28.927°S 151.567°E, near entrance to Sundown National Park, 3.ii.1999, J. Moss and L. Popple; 3 ♂♂, 4 ♀♀, SEQ: 28°50'S 151°28'E, Glenlyon Dam, 1-2.ii.1999, J. Moss and L. Popple; 3 ♂♂, 2 ♀♀, 26°53'13"S 152°12'49"E,

Base of Blackbutt Range, SEQ, 26.i.2002, L. Popple and R. MacSloy; 7 ♂♂, 4 ♀♀, Chinchilla SEQ, 17.iii.2002, L.W. Popple (LWP); 1 ♂, 8.5 km ESE Kaimkillenbun, SEQ, 21.i.2001, A. Ewart A(E). *Cassinia* and grassland, 27°04.30'S 151°29.76'E; 1 ♀, 7.3 km NE Maclagan, SEQ, 21.i.2004, A. Ewart (AE); 27°03.13'S 151°41.64'E. The specimens from the base of Blackbutt Range are illustrated in Fig. 1 (C–D).

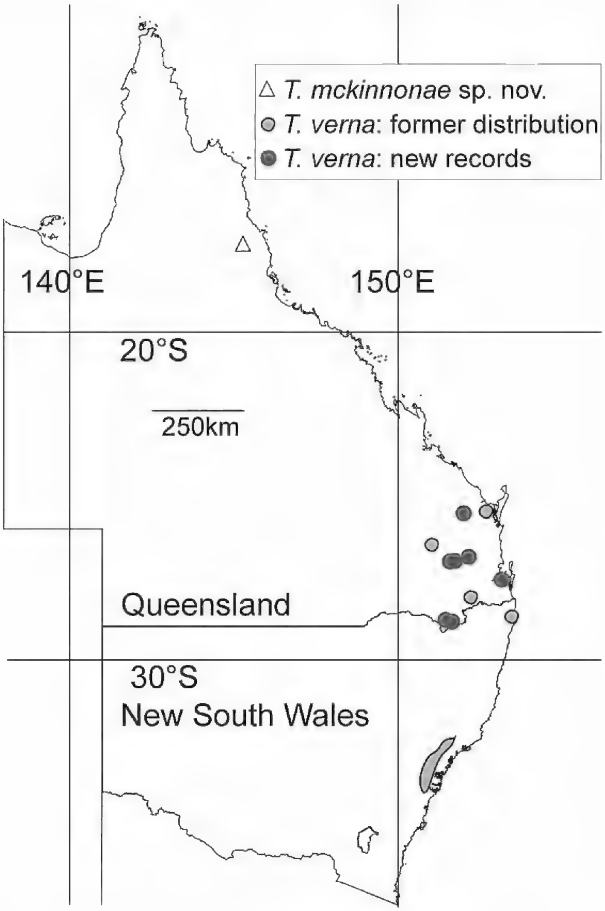

Fig. 3. Map of Queensland and New South Wales showing the distribution of *Toxala* Moulds species. *T. mckinnonae* sp. n. is restricted to a single locality in northern Queensland and *T. verna* (Distant) is scattered in southeastern Qld, northeastern and central eastern New South Wales. The former distribution of *T. verna* was sourced from Moulds (1990). New specimen records are detailed in the text.

Calling songs of *Toxala* cicadas

The calling songs of *Toxala verna* (Distant) and *T. mckinnonae* exhibit clear similarities (Fig. 4). Both species produce a relatively simple repetitive phrase, comprising a train of syllables, each punctuated by brief silences, followed by an echeme, another short period of silence, and then a macrosyllable and a final period of silence before the song repeats. Male wing-clicks are a common component of the song and occur at around the beginning of each phrase (at the start of the train of syllables). Field observations of *T. verna* at Chinchilla and *T. mckinnonae* west of Herberton indicate that, in each species, the female response occurs in the period of silence following each macrosyllable (pers. obs. 2002, 2007); however, no recordings of this behaviour have been obtained.

In *T. verna*, the syllable train has a variable duration (249 ms to 1.886 s) and may be composed entirely of single syllables (8-10 ms duration; Fig. 5) or predominantly composed of double syllables (17-19 ms, Fig. 6); in both cases these are followed by short silences (3-56 ms, Figs 5 and 6). A brief macrosyllable of 22-26 ms occasionally follows, with a silence of 2-22 ms preceding the echeme. The echeme varies considerably in duration (103-830 ms) and is followed by a longer period of silence (38–86 ms). A macrosyllable typically comprising 3-4 (rarely 2) syllables (23-40 ms), followed by another silence (22-165 ms), completes each phrase (Figs 5 and 6). The call has a phrase duration of 0.793 to 2.687 s and a frequency range that extends from 4 kHz (principally from 8 kHz) to >22 kHz. Available recordings indicate that the highest amplitude dominant frequency plateau extends from 16-20.5 kHz. This is at the limits of the recording equipment; therefore the plateau could conceivably extend to higher frequencies.

In *T. mckinnonae* sp. n., the syllable train (581 ms to 1.654 s duration) characteristically begins with a long sequence of single syllables (each 8-9 ms duration) followed by a shorter sequence of double syllables (each 15-16 ms duration), with the sounds in each case punctuated by short silences (8-45 ms, Fig. 7). A brief silence at the end of the train of double syllables (5-10 ms) precedes the echeme. The echeme is produced for 148–263 ms and is followed by a longer period of silence (54–60 ms). A macrosyllable comprising 3-4 syllables (24-36 ms), followed by another silence (21-92 ms), completes each phrase (Fig. 7). The call has a phrase duration of 1.031 to 1.840 s and a frequency range that extends principally from 8.5 to >24 kHz. Available recordings indicate that the highest amplitude dominant frequency plateau extends from 16 kHz to at least 22 kHz; however, as for the *T. verna* recordings, limitations to the sensitivity of the recording equipment could ultimately mean that the true dominant frequency is considerably higher.

Whilst the similarities between the calling songs of *T. verna* and *T. mckinnonae* sp. n. are evident and obvious, a small number of noticeable differences in gross song structure are apparent.

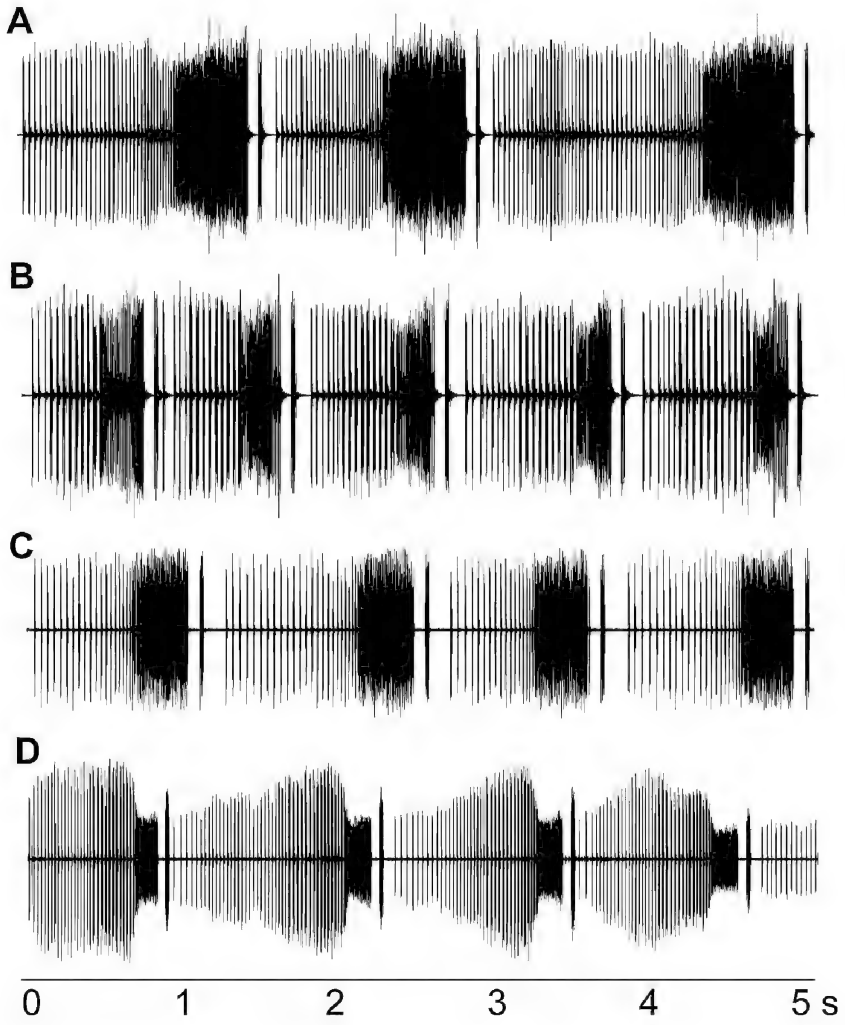

Fig. 4. Waveform plots illustrating the male calling song of *Toxala* Moulds cicadas from different localities in Queensland. (A–C): *T. verna* (Distant) from Chinchilla (26°44'S 150°38'E) base of Blackbutt Range (26°53'S 152°13'E) and 8.5 km ESE Kaimkillenbun (27°04.30'S 151°29.76'E) (this last recording by A. Ewart) respectively. (D): *T. mckinnonae* from 'Hornet Hill' west of Herberton (17°23'S 145°21'E).

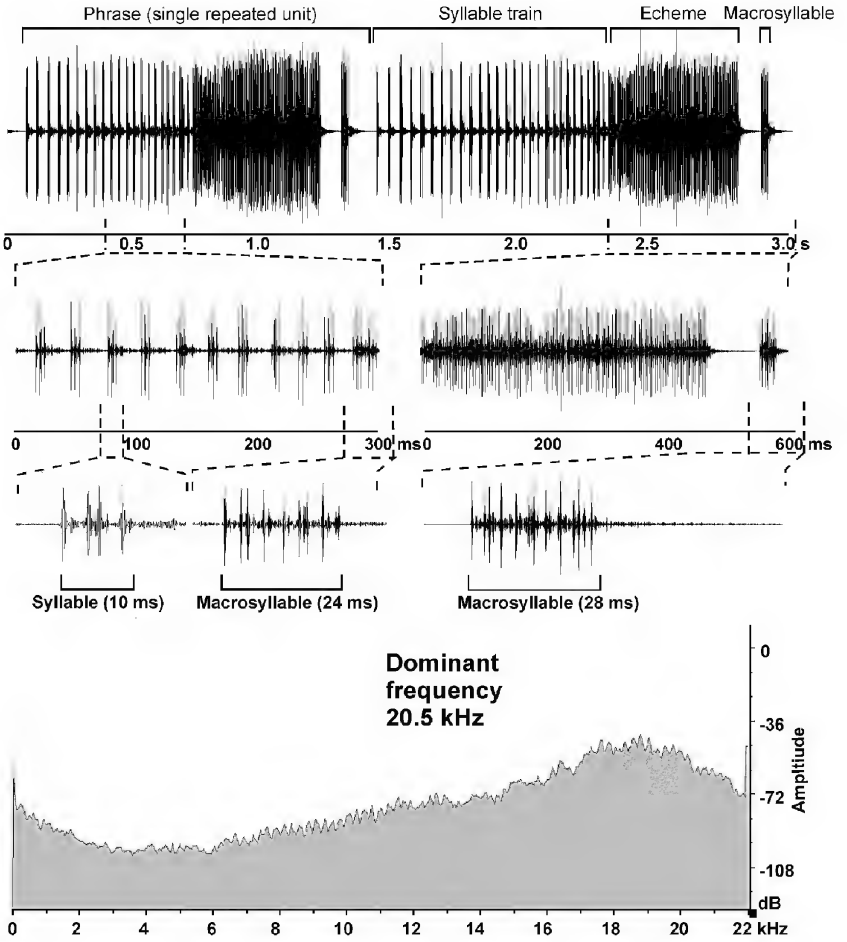

Fig. 5. Male calling song structure of *Toxala verna* (Distant) illustrated in expanded waveform plots. This recording shows a syllable train composed almost entirely of single syllables, which is the typical structure of most recordings of *T. verna.* The spectrogram at the bottom of the figure displays song frequency. This specimen was recorded in the field at Chinchilla (26°44'S 150°38'E) in south-eastern Queensland.

The most obvious difference is in the structure of the syllable trains at the start of each phrase. In *T. verna*, these are almost always composed of single syllables (occasionally with a macrosyllable at the very end; *e.g.* Fig. 5). The only exception is in the recording of an individual from the base of the Blackbutt Range (Fig. 6). In this example, the syllable train is almost entirely

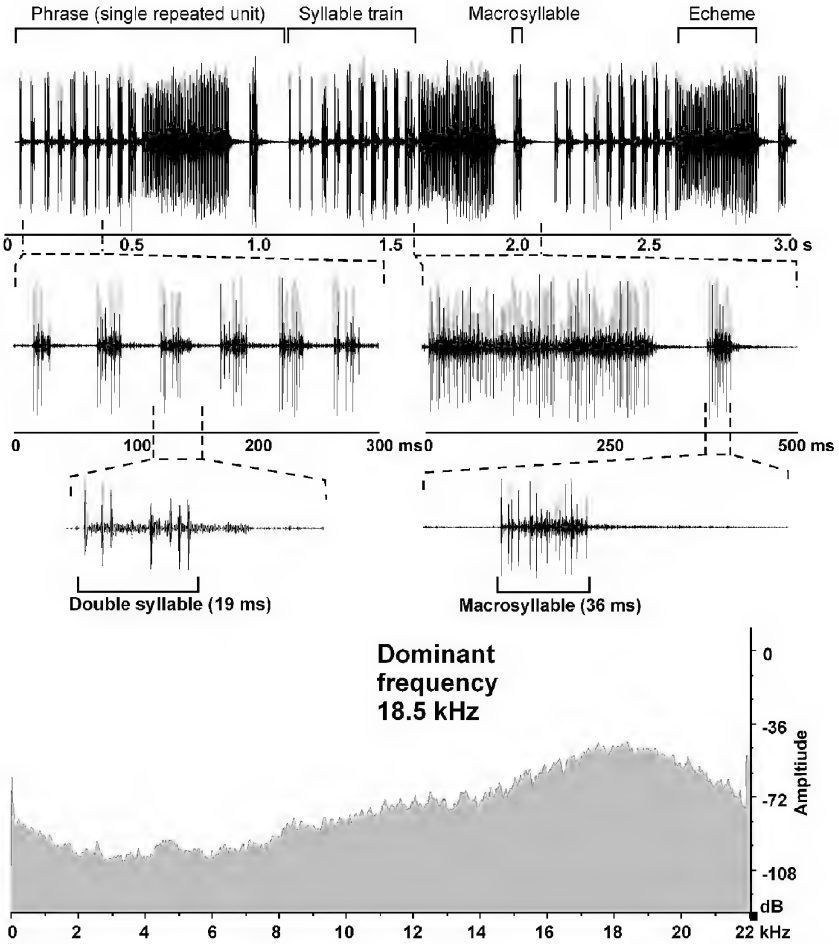

Fig. 6. Male calling song structure of *Toxala verna* (Distant) illustrated in expanded waveform plots. This recording shows a syllable train that predominantly comprises double syllables, which is atypical among the available recordings of *T. verna.* The spectrogram at the bottom of the figure displays song frequency. This specimen was recorded in the field at base of Blackbutt Range (26°53'S 152°13'E) in southeastern Queensland.

composed of double syllables. In contrast, *T. mckinnonae* produces a characteristic long sequence of single syllables, followed by a shorter sequence of double syllables in each syllable train (Fig. 7). Another feature that appears to be unique to *T. mckinnonae* is the amplitude modulation in

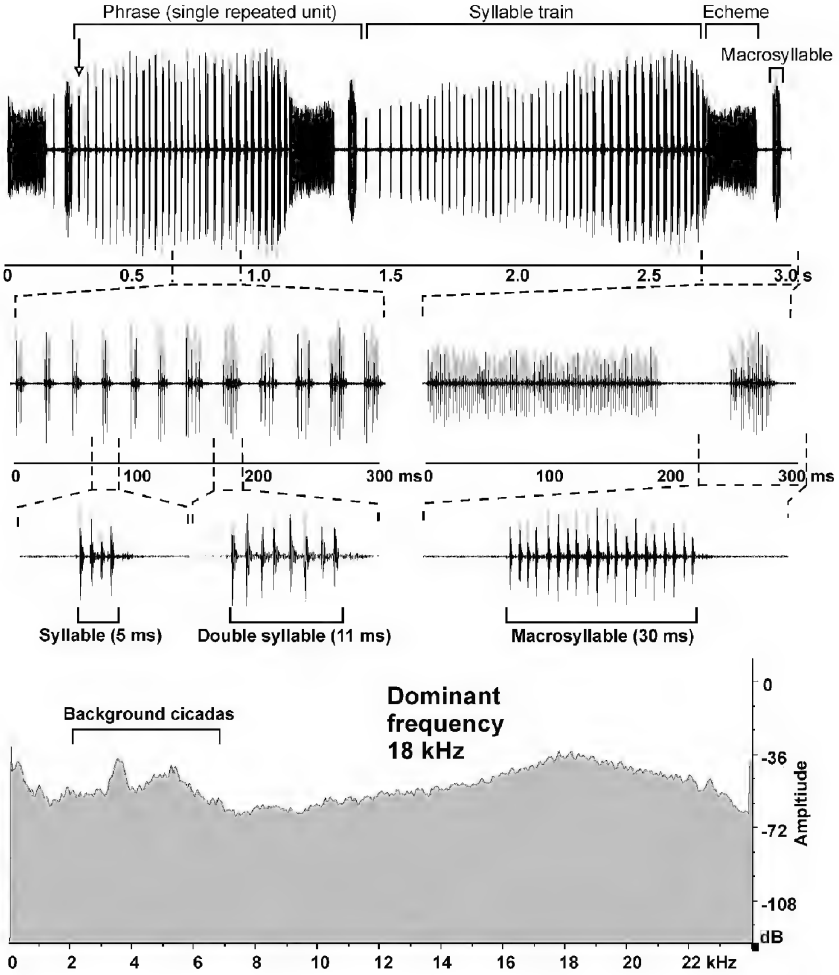

Fig. 7. Male calling song structure of *Toxala mckinnonae* sp. n. illustrated in expanded waveform plots. This recording shows the characteristic structure of *T. mckinnonae*, with regular amplitude modulation and a unique pattern in the syllable train (*cf. T. verna* in Figs 5 and 6). The spectrogram at the bottom of the figure displays song frequency. This specimen was recorded in the field at 'Hornet Hill' west of Herberton (17°23'S 145°21'E) in northern Queensland.

each phrase, whereby amplitude increases markedly as the syllable train proceeds, reduces abruptly during production of the echeme and increases again when the macrosyllable is produced. This distinctive pattern is not

present in any of the *T. verna* recordings, which appear to show little change in amplitude during the production of each phrase.

Acknowledgements

I would like to thank Anne-Marie McKinnon for assistance with finding and locating the new species in the field. Appreciation is also extended to Tony Ewart for making his extensive collection of cicada recordings available. In addition, Tony Ewart and Max Moulds provided helpful comments on the manuscript and Susan Wright (Queensland Museum) kindly arranged deposition and registration of the type material.

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